rzero

Enhancing Building Health: Moving Beyond HVAC

indoor air quality moves into the spotlight

In a country that spends 90% of its time inside, indoor air quality is finally getting the spotlight it deserves. This whitepaper examines the new expectations for indoor air quality, and the challenges organizations face attempting to meet these expectations. It also uncovers why HVAC upgrades fall short of these new standards, and compares how UVC technology and HVAC solutions stack up against a host of measurables.

Around the same time the EPA was working to reduce smog, the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) published their ***Standard 62*** specifying the minimum ventilation requirements for managing indoor air quality. A few decades later, ASHRAE published ***Standard 90.1***, which focuses on energy efficiency of buildings.

For decades, air quality has been about what goes on outdoors. Wildfires, smog, heat, and other factors affecting air quality often make the local news and are usually accompanied by health and safety recommendations encouraging people to stay indoors. But in a country that already spends 90% of its time inside,[1] experts are emphasizing that indoor air is often less safe than outdoor air.

These documents are intended to help Building Managers choose ventilation systems that meet the minimum acceptable indoor air quality standards—not to ensure the health and safety of the people inside the building.

Today, indoor air quality considerations have reached new heights in light of COVID-19 and its variants. Air quality is a significant factor contributing to the virus's spread[2] and is heavily referenced in the new National COVID-19 Preparedness Plan.[3]

While COVID may have been the impetus for a renewed focus on indoor air quality, the importance of indoor air for health and safety is moving far beyond the pandemic. Simply put, emerging evidence indicates that today's HVAC systems, standards, and uses are not enough to ensure the indoor air quality levels expected by healthy businesses and communities. It's time to reevaluate the technologies available to solve these air quality challenges.

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The challenges of achieving the new IAQ expectations with HVAC. According to the EPA, one of the leading causes of poor indoor air quality is poor ventilation.[7] It's time to look closely at how HVAC systems fall short.

Most HVAC systems weren't built for the new standard for healthy indoor air quality

HVAC systems are designed to promote thermal comfort and acceptable indoor air quality (IAQ). But what exactly is considered 'acceptable'?

Essentially, ACH is the number of times per hour that the total air volume in a space is replaced with fresh or filtered air—so an ACH of 4 means the air in a given room is changed four times per hour. For most commercial, non-healthcare buildings, ASHRAE suggests an ACH of 2 to 4 as a minimum removal rate for particulate matter, volatile organic compounds (VOC), and CO_2.[8]

However, for high-risk environments such as hospitals, where ventilation is also targeted at removing disease-causing microbes, ASHRAE recommends an ACH between 6 to 20[9]. The difference between an air change once every 30 minutes and once every 3 minutes is quite drastic. Ensuring maximal health and safety requires a minimum of 6 ACH. In a post-COVID world, organizations of all types can now be considered "high-risk" and therefore, are seeking solutions to provide additional ACH to reduce risk.

Note that while ASHRAE has long published these minimum standards, many schools, offices, and other buildings fall far short.

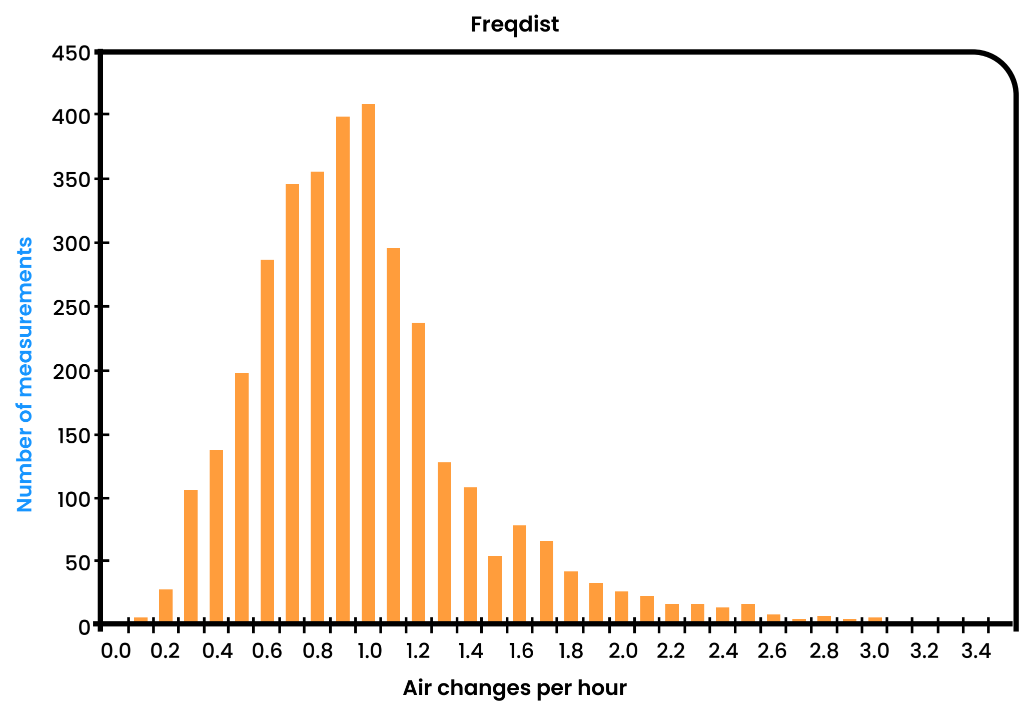

Fig. 2 Frequency distribution of office building outdoor air change rates (Persily, 1989)

HVAC systems don't deliver consistent indoor air quality

For a variety of reasons ranging from inadequate system maintenance to prioritizing thermal comfort above IAQ, air changes per hour can vary from space to space within the same building and over time within the same space, including to levels below ASHRAE's recommended minimums. A 2015 paper[10] found that the air changes in a building ranged from 0.25 to >2.5 ACH due to the effects of temperature, exhaust fans, window openings, and more.Thus, while a building may have a compliant average ACH, occupants may be spending most of their time in a room well-below the minimum ACH.

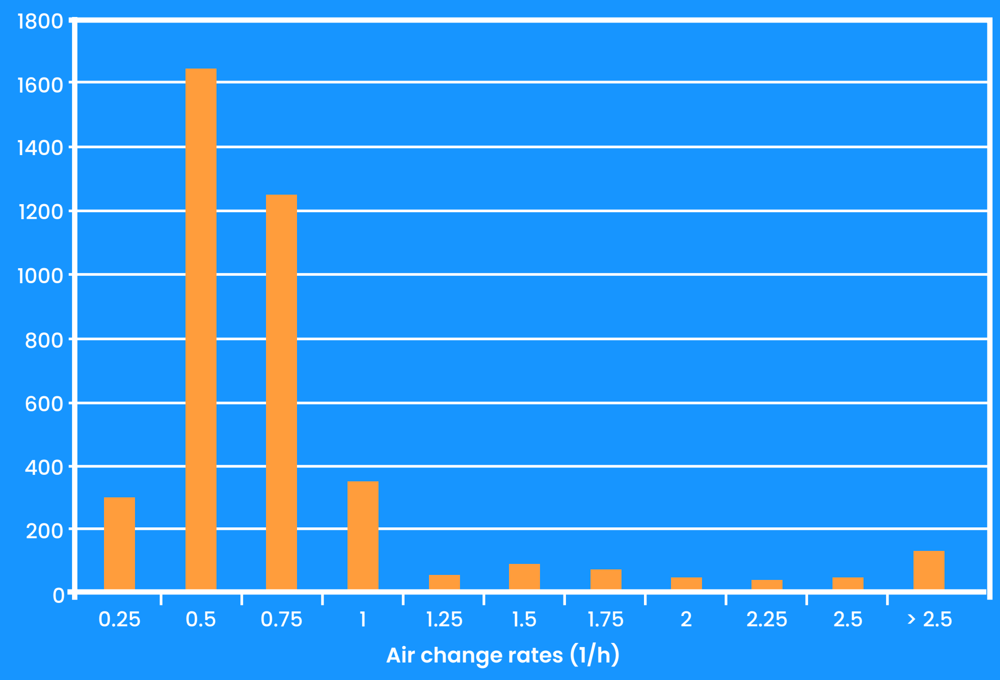

Fig. 4 Distribution of air change rates over one year in an occupied town house (Wallace et al. 2001)

You may wonder how this can happen. Take the example of a typical office conference room on a cold, winter day. As more people enter, their body heat naturally warms up the space, so the HVAC system doesn't need to blow warm air to heat it up as much. However, this means it's also not ventilating the space as much either, leading to increased microbial load where the most people are present. Meanwhile, the HVAC system is wasting energy heating and ventilating the building's empty and unused spaces.

Too many variables: HVAC systems rarely used to optimize indoor air quality

As the name HVAC (Heating, Ventilation, and Air Conditioning) implies, these systems have a lot of jobs on their hands. If the system is poorly designed, operated, or maintained, several issues can arise. As heating and cooling issues are typically the first to be brought up by occupants and therefore resolved, we'll focus on the IAQ issues that tend to go unnoticed.

For example, inadequate system design can mean that air supply and return vents within each room could be blocked or placed in an ineffective location that prevents outdoor air from reaching occupied spaces. Additionally, improperly located intake vents can bring in contaminated air such as vehicle exhaust, boiler/machinery emissions—even fumes from ventilated restrooms and dumpsters.

Saving energy is a must for facilities managers looking to meet environmental standards and lower costs. However, if reducing costs means dialing down system usage, then not enough outdoor air may enter or exit the building, which immediately reduces air quality. Since costs are reviewed at least quarterly while health is often affected over years and decades, operating for cost savings rather than indoor air quality is unfortunately all too common.

Finally, HVAC systems themselves can become a hazard if not adequately maintained. For instance, poorly maintained cooling towers, humidifiers, dehumidifiers, air conditioners, and ducts can be home to a plethora of contaminants—all of which can reach occupied spaces.

Because HVAC has so many jobs, tradeoffs have to be made in its design and operation. Adding hospital-grade disinfection to that list of jobs significantly complicates an already challenging balance of thermal comfort, ventilation, and energy costs.

MERV filters: good tool, bad place

MERV filters are a tempting choice for reducing the spread of SARS-CoV-2 and other airborne microorganisms since they are already in our buildings. These filters, physically located in the HVAC system, remove contaminants from air before it is ventilated into a room. But, the majority of harmful microbes are introduced by individuals already in-room, rather than from room to room via the ventilation system.[12] Accordingly, these filters do little for in-room risk as they clean air within the HVAC systems, not the air in the rooms where microbes are actually being shed. As Dr. Nardell of Harvard Medical School puts it, "there is little comfort in knowing that the air will be decontaminated only after it leaves the room."[13]

Moreover, added filtration increases flow resistance and, depending on fan load capacity, can reduce room ventilation, making transmission in a given space more likely.

Additionally, MERV filters require higher fan capacity and, thus, more energy and costs to pump air through them.

HVAC upgrades are costly and time-consuming.

At this point you may be wondering whether your building's HVAC system can be optimized for indoor air quality. Typically, commercial HVAC systems run at about 70-80% of capacity and therefore can only be increased 20-30% without significant upgrades. Unfortunately increasing an ACH of 2 by 30%, only gets you to 2.6 ACH, still well below the recommended levels of 6-12 ACH for the higher-risk environments we now occupy. To achieve this healthy range of 6-12 ACH may require upgrades to a system's blowers, heating, cooling, dehumidification systems, and ductwork, costing in the millions of dollars for every 100,000 square feet.

Budget aside, these complex upgrades require months to complete, during which building managers run into all sorts of construction-related problems. For example, there may not be sufficient space in the ceiling and crawl spaces to allow for more extensive ductwork, which means the building has to be retrofitted, making the project more expensive, complex, and time-consuming. Moreover, projects of this nature also require parts of the building to be vacant for months, leading to IT and facility headaches as occupants need to be reshuffled.

So just how much time, cost, and inconvenience will upgrading your HVAC set your organization back?

The takeaway: modifying the operation of an HVAC system to increase biosafety is less convenient, more costly, and less sustainable than other emerging technologies which we explore in the next section.

There's a proven technology that could change all of this. It's called upper-room ultraviolet germicidal irradiation (UR-UVGI), and it's recommended by the CDC, the EPA, ASHRAE, and The White House. UR-UVGI achieves healthcare-level biosafety (6 to 12 eACH) for a fraction of the cost, time, and complexity.

Healthy Indoor Air Quality isn't a nice to have. It's expected. Meet R-Zero.

As the concern over respiratory viruses continues, building managers are scrambling for ways to reduce the risk of airborne exposure—and for good reason: a majority of employees would consider looking for another job if air quality and disinfection standards are not met.

Upper-room UVGI devices, such as the R-Zero Beam, effectively, efficiently, and sustainability inactivate airborne microorganisms in rooms where transmission happens. By filling the disinfection gaps left by HVAC, buildings of all types can improve biosafety while meeting sustainability goals and lowering costs.

The efficacy of upper-room UVGI solutions is measured in equivalent ACH (eACH) - a direct comparison to an HVAC's ACH rating. Remember that an HVAC system designed to run at ACH 2 could only be tuned up to – at most – an ACH of 2.5. The R-Zero Beam can add more than 10 eACH to a room, reducing exposure to microbes by over 70%. Beam is a targeted, always-on, sustainable, cost-effective way to increase a building's biosafety.

HVAC upgrades vs R-Zero: a side-by-side

	Modifying HVAC Operation	R-Zero Beam
Effectiveness	Commercial HVAC systems are typically designed to operate at 2 to 4 ACH for general office areas. With modifications, they may have the capacity to deliver 4-6 ACH. Achieving 6-12 ACH, as recommended by ASHRAE, is often not possible for common buildings. To do so may require plant upgrades to increase the duct size, costing upwards of $30 to $40 per square foot.	Beam can add 10+ eACH, reducing exposure risk by 70% or more, at a lower total equipment and installation cost of $5 to $7 per square foot.
Cost	Because of the design of modern HVAC systems, achieving a higher ACH requires running all systems at a higher rate (fan, heating, cooling, dehumidifying), increasing HVAC energy costs by an average of 19% per additional ACH.	Beam's TCO is a fraction of the cost of upgrading a commercial HVAC system. Beam's average energy costs on a per-additional-eACH basis are 92% lower than HVAC.
Sustainability	Additional energy required translates directly into additional GHG emissions. HVAC systems already account for 35% of a commercial building's energy use, and additional energy required would significantly increase this. A large increase in energy consumption, and the associated GHGs, would come under serious scrutiny as building owners and operators strive to meet green building standards.	Energy usage by the HVAC system varies widely by climate zone, HVAC system type, and energy source. Across climate zones, HVAC system types, and energy sources, Beam uses, on average, 93% less energy (and related GHG emissions) per additional ACH than the HVAC system.
Consistency	Most HVAC systems are optimized for thermal comfort and deliver different amounts of air based on temperature set points in different zones. A building that receives 3 ACH on average overall may have some areas that receive less than 1 ACH and others that receive 6 ACH.	Beams provide a consistent and predictable level of disinfection on a space-by-space basis, operating adaptively to conditions in the room to maximize both disinfection and energy efficiency in each specific space.
Targeting	Levels of particulate load can vary dramatically within a building, but central HVAC systems are unable to target specific rooms or spaces. Additionally, HVAC systems can only remove microorganisms by pulling them out of the room. It cannot achieve the elimination of microorganisms in the room where active virus elimination actually happens.	R-Zero's proprietary risk model based on the Wells-Riley equation dictates where Beam is installed, ensuring that the spaces where viral exposure risk is highest receive the largest risk reduction. Additionally, Beams disinfect in the room where active virus elimination happens.
Comfort	An increased fan speed to achieve greater ACH may surpass the heating, cooling, and dehumidification capacity of the system, resulting in uncomfortable temperatures and/or humidity.	Beams operate silently in the background, doubling or tripling the eACH of a space while having virtually no impact on the ability of the HVAC system to keep occupants comfortable.

Take your first step towards healthier buildings with R-Zero.

R-Zero is redefining building health standards with a science-first, sustainable and cost-effective solution. In addition to Beam, R-Zero offers a more-targeted disinfection solution for high-risk areas, including conference tables, restrooms, and reception areas, the R-Zero Vive.

[1] https://www.epa.gov/report-environment/indoor-air-quality#note10
[2] https://www.washingtonpost.com/politics/2022/06/21/ventilation-is-crucial-until-recently-it-took-backseat-other-covid-measures
[3] https://www.npr.org/sections/health-shots/2022/03/14/1086125626/school-air-quality
[7] https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality
[8] https://jamanetwork.com/journals/jama/fullarticle/2779062
[9] https://jamanetwork.com/journals/jama/fullarticle/2779062
[10] https://onlinelibrary.wiley.com/doi/abs/10.1111/ina.12193
[11] https://onlinelibrary.wiley.com/doi/full/10.1111/php.13421
[13] https://time.com/6143799/covid-19-indoor-air-cleaning/

Improving indoor air quality quickly and effectively is possible. Learn more about R-Zero by paying us a visit at:

ABOUT R-ZERO

R-Zero is the first biosafety technology company dedicated to making shared indoor spaces safe and clinically clean. Backed by Mayo Clinic and the earliest investors in Google, Amazon, Tesla, and SpaceX, R-Zero was founded to help organizations protect the health of people they serve and is dedicated to developing the most effective, innovative disinfection technologies to reduce the spread of all infectious diseases. R-Zero's first product, Arc [an IoT-enabled, whole-room UV disinfection device], is currently enabling a higher level of health safety, without the use of chemicals, for both public and private sector organizations. Today, R-Zero is pioneering the first continuous, automated disinfection ecosystem, enabling every organization to measure and manage indoor health with a previously unavailable level of sophistication and ease. Informed by data science and built with AI, ML, and IoT-connected hardware, R-Zero's intelligent biosafety platform provides greater visibility, automation, and even smarter risk reduction within the indoor spaces where people spend their time. R-Zero is backed by leading venture capital firms DBL Partners, World Innovation Lab, and SOSV/HAX and thought leaders from hospitality, sports, commercial real estate, impact, and other industries. For more information, visit www.rzero.com.